I, Ikuzo Tanaka, Declare:

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2. To the best of my ability, I translated:

Japanese Patent Application No. 2002-229522

from Japanese into English and the attached document is a true and accurate English translation thereof.

3. I further declare that all statements made herein are true, and that all statements made on information and belief are believed to be true; and further that willful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

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SPECIFICATION

Title of the Invention

LAMINATE COIL AND BRUSHLESS MOTOR COMPRISING SAME

Claims:

1. A laminate coil for an integral *n*-phase motor (*n* is a natural number of 2 or more) having pluralities of coil poles formed by patterned conductor coils formed in a laminate constituted by pluralities of insulating layers, said laminate coil comprising input and output terminals formed on an outer surface of said laminate, a first connecting line connecting said input terminal to said coil poles, and second connecting lines series-connecting coil poles having the same polarity, said first and second connecting lines being formed by conductor patterns, and said coil poles being formed on pluralities of insulating layers sandwiched by said first and second connecting lines.

2. The laminate coil according to claim 1, wherein the number of said coil poles is an integral multiple of *n* and equal in each phase.

3. The laminate coil according to claim 1 or 2, wherein n is 2 or 3.

4. The laminate coil according to any one of claims 1 to 3, wherein it comprises a through-hole for receiving a rotation shaft and/or a bearing of a brushless motor substantially in a center portion of said laminate.

5. The laminate coil according to claim 4, wherein said first connecting line comprises an annular conductor portion surrounding said through-hole, a first conductor portion connecting said annular conductor portion to said input terminal, and second conductor portions extending from said annular conductor portion and connected to said coil poles.

6. The laminate coil according to any one of claims 1 to 5, wherein said input and output terminals and said first connecting line are formed on one main

surface of said laminate.

7. The laminate coil according to any one of claims 1 to 6, wherein each of said second connecting lines comprises two arcuate portions having different radii, and a radial portion connecting said two arcuate portions.

8. A laminate coil for an integral three-phase motor comprising pluralities of coil poles formed by patterned conductor coils in a laminate constituted by pluralities of insulating layers, said laminate being formed in the shape of a flat rectangular plate, and each of one input terminal and three output terminals being formed at four different corners on the same main surface of said laminate.

9. The laminate coil according to any one of claims 1 to 8, wherein said coil poles are constituted by connecting coils formed on pluralities of insulating layers such that they overlap in a lamination direction, said coil being constituted by at least a first coil wound clockwise from inside to outside and a second coil wound clockwise from outside to inside, said first and second coils being connected via through-holes formed in said laminate, whereby said first and second coils have the same winding direction.

10. The laminate coil according to any one of claims 1 to 9, wherein different-phase coil poles are arranged around a motor shaft at an equal angular interval.

11. The laminate coil according to claim 10, wherein coil poles having the same polarity are arranged at rotationally symmetric positions of 180° around a rotation center of said motor shaft.

12. The laminate coil according to any one of claims 1 to 11, wherein said coils are fan-shaped spiral coils each having an open angle of 55° or less with said motor shaft as a center.

13. A brushless motor comprising the laminate coil recited in any one of claims 1 to 12 as a stator, said laminate coil being arranged such that it opposes a rotor comprising a permanent magnet having different magnetic poles

alternately via a magnetic gap.

14. The brushless motor according to claim 13, further comprising an electric signal controller for periodically supplying electric current to each of different-phase coil poles of said laminate coil.

DETAILED DESCRIPTION OF THE INVENTION

[0001]

Field of the Invention

The present invention relates to a small, thin, inexpensive brushless motor, and a laminate coil used therein.

[0002]

The miniaturization of electronic equipments results in stronger demand to provide smaller and thinner motors for use therein. As such a motor, Japanese Utility Model Laid-Open No. 58-172345, for instance, discloses a flat brushless motor comprising stator coils and a rotor having a permanent magnet opposing thereto, stator coils being constituted by laminating pluralities of sheet coils each formed by a spiral conductor pattern formed on an insulating substrate.

In this flat brushless motor, as shown in Figs. 14 to 16, motor magnetic poles are formed by 3-phase, 8-pole sheet coils 50 fixed to a stator yoke such that they are opposing to a magnetic pole surface of the rotor magnet 100. A single-phase coil is formed by one 8-pole flat coil, and adjacent coil poles 200 are series-connected with opposite polarities facing each other. Pluralities of sheet coils 50 are concentrically laminated, each coil 50 being held by a coil holder 125 such as a yoke, a print circuit board (PCB), etc., and ends of each coil 50 being connected to a pattern surface of a print circuit board (PCB) 120 by solder, etc. Each sheet coil 50 is a toroidal conductor pattern formed on a thin insulating sheet 210 by etching, plating, etc., which is provided with coil poles 200.

[0003]

JP 64-59902 A discloses a laminate coil for a brushless motor, which is obtained by forming as coil sheets coil conductor patterns on green sheets formed by ceramic powder, for instance, by a screen printing method, etc., laminating pluralities of coil sheets, providing connection between the coil

conductor patterns via through-holes, and integrally burning the coil conductor patterns with the green sheets.

[0004]

Problems to be Solved by the Invention

However, such conventional coils suffer from the following problems. In the coil disclosed by the first prior art document, because three-phase coils are obtained by forming toroidal pattern conductors for coil poles on thin insulating sheets by etching, plating, etc., and disposing them with displacement of a predetermined angle in a circumferential direction, laminated coil layers should be bonded by uniform adhesive layers; positional displacement between the bonded coil layers causes short-circuiting, etc. between the coil poles, resulting in the likelihood of uneven rotation and torque ripple; sheets of polyimides, polyesters, etc. used as insulating sheets have limited mechanical strength, generally necessitating the insulating sheets to be disposed on the PCB or the yoke, thereby making further miniaturization and thinning difficult.

In the laminate coil of in the second prior art document, in which green sheet substrates having external terminal electrodes are laminated with pluralities of coil sheets, circular portions, on which coils are formed, and rectangular portions, on which external terminal electrodes are formed, are different in thickness, so that the laminate coil cannot be produced at a high productivity. In addition, to provide the external terminal electrodes with improved mechanical strength, green sheet substrates having no coil conductor patterns formed should be thick, resulting in a thicker laminate coil. In addition, the existence of the external terminal electrodes enlarges the area of the laminate coil, resulting in a larger brushless motor.

Accordingly, an object of the present invention is to provide a small, thin laminate coil having high strength and productivity and excellent motor efficiency free from uneven rotation and torque ripple, and a brushless motor

comprising such a laminate coil.

[0005]

Means for Solving the Problems

The first invention is a laminate coil for an integral *n*-phase motor (*n* is a natural number of 2 or more) having pluralities of coil poles formed by patterned conductor coils formed in a laminate constituted by pluralities of insulating layers, comprising input and output terminals formed on an outer surface of the laminate, a first connecting line connecting the input terminal to the coil poles, and second connecting lines series-connecting coil poles having the same polarity, the first and second connecting lines being formed by conductor patterns, and the coil poles being formed on pluralities of insulating layers sandwiched by the first and second connecting lines. The number of coil poles is preferably an integral multiple of *n* and equal in each phase. Though the number *n* of phases of the motor may be selected from a natural number of 2 or more, when *n* is 2 or 3, it is possible to get stable characteristics, even if the number of coils is limited to a number so as to provide the minimum motor output from a viewpoint to miniaturize the size of motor.

The laminate has a through-hole for receiving a rotation shaft and/or a bearing of a brushless motor substantially in a center portion thereof. The first connecting line comprises an annular conductor portion surrounding the through-hole, a first conductor portion connecting the annular conductor portion to an input terminal, and second conductors extending from the annular conductor portion and connected to coil poles. The input terminal, the output terminal and the first connecting line are preferably formed on one main surface of the laminate. The second connecting lines have preferably two arcuate portions having different radii and a radial portion connecting the two arcuate portions.

In the laminate coil of the present invention, the coils constituting

multiple-phase coil poles are formed on a surface of the same layer, and arranged at symmetric positions of 180° with the motor shaft as a center such that adjacent coils do not constitute coil poles having the same polarity, and connected by the second connecting lines. Such structure provides the coil poles having large numbers of winding, and improves the motor characteristics because a gap between each coil pole and the permanent magnet of the rotor can be substantially the same. To obtain the stable rotation of the motor, the total number of coil poles is preferably the same in each phase.

[0006]

The center of through-hole formed substantially in a center portion of the laminate is substantially aligned with the center of the rotor shaft. Accordingly, when the annular conductor portion of the second connecting line is arranged such that it surrounds the through-hole, the rotation of the motor is not hindered. With the second conductors connected to the coil poles and the first conductor portion connected to the input terminal radially extending from the annular conductor portion, the effective length of the coil increases if slightly, resulting in an improved motor performance.

In the present invention, the input and output terminals and the first connecting line are formed on one main surface of the laminate, making connection to the print circuit board (PCB) easy. The input and output terminals are preferably in a land grid array (LGA) or a ball grid array (BGA).

[0007]

The second invention is a laminate coil for an integral three-phase motor comprising pluralities of coil poles formed by patterned conductor coils in a laminate constituted by pluralities of insulating layers, the laminate being formed in the shape of a flat rectangular plate, and each of one input terminal and three output terminals being formed at four different corners on the same main surface of the laminate.

Though the laminate coil may be annular because the coil poles are annularly formed around the motor shaft, an annular structure needs other means such as die-punching, etc., making the production steps of each laminate coil complicated. According to the present invention, it is easy to form each laminate coil from a laminate substrate comprising pluralities of laminates, as described later. With the input and output terminals formed at four different corners on the same main surface of the laminate in the shape of a flat rectangular plate such that they do not overlap the coil poles in a lamination direction, thereby preferably making the laminate coil substantially not enlarge as well as making the motor performance not deteriorate. Because the input and output terminals can be made relatively large, it is possible to have improved terminal connection strength with the PCB, thereby effectively utilizing portions not occupied by the coil poles in the laminate.

[0008]

In the first and second laminate coils, the coil poles are constituted by connecting coils formed on pluralities of insulating layers such that they overlap in a lamination direction. The coil is preferably constituted at least by a first coil wound clockwise from inside to outside and a second coil wound clockwise from outside to inside, the first coil and the second coil being connected via a through-hole formed in the laminate, whereby the first and second coils have the same winding direction.

With such structure, the first and second coils function as one coil pole when electric current is supplied in a constant direction. Accordingly, the coil pole has a large number of winding, providing a motor with a higher torque.

Different-phase coil poles are preferably arranged around the motor shaft at an equal angular interval. The coil poles having the same polarity are preferably arranged at rotationally symmetric positions at 180° around the rotation center of the motor shaft. The arrangement of the coil poles having

substantially the same size around the motor shaft at an equal angular interval causes each coil pole to generate a counter electromotive force symmetrically around the motor shaft, resulting in an improved precision of the motor rotation.

The coil is preferably a fan-shaped spiral coil having an open angle of 55° or less with the motor shaft as a center. With the fan-shaped spiral coil arranged around the motor shaft as a center, line portions radially extending from the rotation shaft as a center preferably correspond to an effective coil length contributing to torque characteristics, resulting in a high torque. The open angle of the spiral coil is determined by the width of a conductor pattern constituting the spiral coil, the numbers of coils and phases in the motor, etc. In the case of a three-phase, six-pole motor, the upper limit of the open angle is preferably 55°.

[0009]

The third invention is a motor comprising any one of the laminate coil of the first invention or the second invention, the brushless motor comprising the above laminate coil as a stator, the laminate coil being arranged such that it opposes via a magnetic gap a rotor comprising a permanent magnet having alternately different magnetic poles. The brushless motor of the present invention preferably comprises electric signal controllers for periodically supplying electric current in every different-phase coil poles in the laminate coil.

[0010]

Operative Embodiments for Practicing the Invention

(First Embodiment)

The present invention will be explained using a lamenter coil of one embodiment of the present invention and a brushless motor comprising the same as follows.

Fig. 1 is a perspective view showing the laminate coil according to the first embodiment, and Fig. 2 is an exploded view showing its internal structure.

This laminate coil, which integrally comprises pluralities of coil poles, may be formed by printing a conductive paste based on Ag, Cu, etc. on green sheets of a low-temperature co-fired ceramic (LTCC) having a thickness of 20 to 200 μm to form desired conductor patterns, and laminating and burning pluralities of green sheets having conductor patterns. The conductor patterns constituting the coil poles are preferably as wide as about 100 to 400 μm.

[0011]

One example of methods for producing the laminate coil of the present invention will be explained in detail referring to Figs. 9 and 10. First, a ceramic slurry comprising ceramic powder, a binder and a plasticizer is applied onto a carrier film made of polyethylene terephthalate, etc. in a uniform thickness by a known sheet-forming method such as a doctor blade method, etc., to form a green sheet as thick as several tens to hundreds of micron meters. The dried green sheet is cut to a predetermined size without removing the carrier film. The ceramic powder may be, for one instance, a low-temperature-sinterable dielectric material comprising Al_2O_3 as a main component, and at least one of SiO_2, SrO, CaO, PbO, Na_2O and K_2O as an additional component, for another instance, a low-temperature-sinterable dielectric material comprising Al_2O_3 as a main component, and at least one of MgO, SiO_2 and GdO as an additional component, and, for still another instance, a low-temperature-sinterable magnetic ceramic material comprising at least one of Bi_2O_3, Y_2O_3, $CaCO_3$, Fe_2O_3, In_2O_3 and V_2O_5, thereby subjecting the ceramic components skillfully to low-temperature sintering.

This embodiment used a dielectric ceramic comprising Al, Si, Sr and Ti as main components and Bi as an additional component. The main components of this dielectric ceramic were 10 to 60% by mass (based on Al_2O_3) of Al, 25 to 60% by mass (based on SiO_2) of Si, 7.5 to 50% by mass (based on SrO) of Sr, and 20% by mass or less (based on TiO_2) of Ti, assuming that the

total of Al, Si, Sr and Ti is 100 % by mass in term of Al_2O_3, SiO_2, SrO and TiO_2, respectively. The additional component was 0.1 to 10% by mass (based on Bi_2O_3) of Bi, per 100% by mass of the main components. This dielectric ceramic has a dielectric constant of 7 to 9, a three-point bending strength of 240 MPa or more (measured according to JIS R 1601 on a sample of 36 mm in length, 4 mm in width, 3 mm in thickness, and 30 mm in distance between fulcrums), and a Young's modulus of 110 GPa or more, indicating that it has high bending strength and Young's modulus as LTCC.

[0012]

After forming conductor patterns for coils (not shown), input and output terminals, etc. described later on such green sheets, they were laminated in a predetermined order and compressed to form a planar laminate 300 having a thickness of about 0.4 mm. Through-holes (not shown) were formed in the green sheets to properly connect the conductor patterns on the different sheets, thereby connecting coil poles. The laminate was punched in a portion corresponding to a motor shaft by a die, and worked by laser to form a through-hole 10 having a diameter of 2 mm.

Formed on a main surface of the planar laminate by a steel blade were pluralities of parallel dividing grooves 320, and pluralities of dividing grooves 320 perpendicular to these dividing grooves 320 each as deep as 0.1 mm. The depth of the dividing grooves 320 is preferably within a range of 50 to 300 μm for easiness of division, handling, etc. Thereafter, the planar laminate 300 was degreased and sintered to form a laminate substrate 300 (assembly of laminate coils) of 65 mm x 60 mm x 0.3 mm. Input and output terminals, etc. of the laminate coil formed on an outer surface of the laminate substrate 300 were plated with Ni and Au by an electroless plating method. After plating, the laminate substrate 300 was divided along the grooves 320 to provide laminate coils 1 of 8 mm x 8 mm x 0.3 mm for brushless motors as shown in Fig. 1.

[0013]

Referring to Fig. 2, the internal structure of the laminate coil will be explained in a lamination order. This laminate coil is used for a brushless motor using a three-phase driving power source, having an equivalent circuit shown in Fig. 3.

Formed on a lowermost layer, first layer, are second connecting lines 300a, 300b, 300c for connecting coil poles having the same polarity. These second connecting lines are arranged around a motor shaft described later at an equal angular interval, and are constituted by two arcuate portions extending around the motor shaft as a center, and radial portions connecting the two arcuate portions.

In this embodiment, the second connecting lines were constituted as described above to connect to coil poles having the same polarity arranged at symmetric positions of 180° with the motor shaft as a center, the two arcuate portions are arranged on a circumference having a center at the motor shaft, the torque characteristics of the motor are improved if slightly, without hindering the rotation characteristics of the motor.

Though the second connecting lines are formed inside the laminate, they may be formed by printing or transferring a conductive paste on or onto the main surface of the laminate. In that case, at least one green sheet can be omitted, preferably resulting in a thinner laminate coil slightly.

[0014]

Laminated on the first layer is a second layer, on which pluralities of coils are formed. These coils are arranged around the motor shaft at an equal angular interval, constituting multiple-phase coil poles. Fig. 4(a) is an enlarged plan view showing pluralities of coils formed on the second layer. In this embodiment, six coils 251g, 252g, 253g, 251h, 252h, 253h constituting three-phase coil poles are formed on the same layer at an interval of 60°.

The above coils are constituted by the first coils 251h, 252h, 253h wound clockwise from outside to inside, and having through-holes (shown by black circles in Fig. 2) for connecting to coils formed on the another layer at outer ends and the second coils 251g, 252g, 253g wound clockwise from outside to inside, and having through-holes for connecting to coils formed on the another layer at inner ends. The first coils and the second coils are arranged around the motor shaft alternately, as shown in the Figure.

In this embodiment, coils having rotational symmetry of 180° with respect to the motor shaft are series-connected by the second connecting lines, resulting in coil poles having the same polarity. Namely, the first coil 251h and the second coil 251g are connected via the second connecting line 300a, the first coil 252h and the second coil 252g are connected via the second connecting line 300b, and the first coil 253h and the second coil 253g are connected via the second connecting line 300c, respectively constituting coil poles in different phases. In other words, the connecting line 300a constitutes a middle point of the second-phase coil pole 61 shown in Fig. 3, the connecting line 300b constitutes a middle point of the fist-phase coil pole 60, and the connecting line 300c constitutes a middle point of the third-phase coil pole 62.

[0015]

Disposed on the second layer is a third layer, on which pluralities of coils are formed. In this embodiment, as shown in Fig. 4(b), pluralities of coils are six coils 251e, 252e, 253e, 251f, 252f, 253f constituting three-phase coil poles on the same layer at an interval of 60° around the motor shaft, each being a four-turn spiral coil. When the coils formed on the second layer are the first coils wound clockwise from inner side to outside, the coils formed on the third layer overlapping these coils in a lamination direction are formed as the second coils wound clockwise from outside to inside, and when the coils formed on the second layer are the second coils, the coils formed on the third layer on this

layer are the first coils, and the corresponding coils on the second and third layers are connected via through-holes in the same winding direction.

[0016]

The fourth layer are formed substantially equally with the second layer, and the fifth layer are formed substantially equally with the third layer, and are subjected to laminating sequentially. As spiral coils of the same phase formed on the second to fifth layers and overlapping in a lamination direction are constituted by the first coil wound clockwise from inside to outside and the second coil connected to the outer end of the first coil and wound clockwise from outside to inside and they are wound in the same direction, the first and second coils function as one coil pole when electric current is supplied in a constant direction thereto. In this embodiment, coil poles of the same polarity each having 4 turns, which are formed in two-dimensionally different regions, are connected to have 32 turns per one phase, thereby making it possible to provide a motor with high torque. The number of turns of the coils can be easily adjusted by increasing or decreasing the number of layers, on which the coils are formed.

[0017]

The detailed structure of the coil will then be explained. Fig. 5(a) shows the first coils 251h formed on the second layer, and Fig. 5(b) shows the third coils 251f formed on the third layer.

In this embodiment, each coil is a four-turn spiral coil. To improve torque performance, the number of turns in each coil is preferably as many as possible. However, there occur problems such that if a conductor pattern constituting each coil is made narrower to increase the number of turns, DC resistance increases, and in addition, a coil-forming region is restricted by the number of phases and size of the motor. Therefore, the number of turns in each coil is preferably 2 to 6.

Each coil is preferably fan-shaped. An open angle θ of each coil is determined by the numbers of phases and coils in the motor, etc., and properly set such that adjacent coils are not in contact with each other. In this embodiment, the open angle θ of each coil is 50°. Fig. 5(c) shows another example of the preferred structures of the coil. When coil line portions (effective length of coil: L) contributing to torque characteristics radially extend from the rotation shaft as a center as shown in the figure, power generated most efficiency acts to rotate the motor, resulting in high torque. Circumferential portions of the coil not contributing to torque characteristics are circular around the motor shaft as a center, so as not to hinder the rotation performance of the motor.

[0018]

As shown in a partial cross-sectional view taken along with the line A-A' of the laminate coil in Fig. 6, coils of the same phase are preferably laminated in a manner such that their conductors do not overlap in a lamination direction. In a case where there are small gaps between the coils adjacent in a lamination direction, the arrangement and compression of the coils such that their conductors overlap in a lamination direction cause the deformation of the coil conductors, resulting in uneven compression power between portions having the conductors and those having no conductors, and thus the likelihood of delamination (peeling of layers) and small cracking. Accordingly, when constituted as described above, the deformation and strain of coil conductors are reduced, thereby suppressing delamination, etc. Because the green sheets are deformed easily, the coils are substantially formed densely, thereby making it possible to increase conductor occupancy.

[0019]

The same conductive paste as that for the coils was printed on the sixth layer, the upper layer thereof, to form an input terminal IN and output terminals

OUT1 to OUT3, and the first connecting line for connecting the coil poles. The first connecting line was constituted by an annular conductor portion 210 surrounding the through-hole 10 formed substantially in a center portion of the laminate, a first conductor portion 200 connecting the annular conductor portion 210 and the input terminal IN, and second conductor portions 201a~c extending from the annular conductor portion 210 and connected to the coil poles.

Thus, as shown in two points of dashed lines in Fig. 8, the fist-phase coil pole 60 arranged between the input terminal IN and the output terminal OUT1 was formed by the coils 252a to 252h, the second-phase coil pole 61 arranged between the input terminal IN and the output terminal OUT2 was formed by the coils 251a to 251h, and the third-phase coil pole 62 arranged between the input terminal IN and the output terminal OUT3 was formed by the coils 253a to 253h.

The through-hole 10 formed in a substantially center portion of the laminate has a center substantially in alignment with the center of the rotor shaft. Because the through-hole 10 is formed by die-punching or laser-cutting the laminate, etc., in a different step from those forming the coils, the input and output terminals, etc., the through-hole may be displaced from the desired position. In such case, as shown in fig. 7, the formation of the annular conductor portion 210 such that it surrounds the through-hole makes it easy to confirm the positional displacement of the center 410 of the through-hole from the center 400 of the annular conductor portion 210, and the measurement of the positions of the respective centers by a measurement equipment such as a three-dimensional meter, etc. the distance of displacement can easily be found. As a result, it can be easily and quantitatively determined whether the laminate coils are good or bad.

Thus, the laminate coil of 8 mm x 8 mm x 0.3 mm for a brushless motor was produced. The formation of a coating layer on the main surface of the laminate coil with an overcoat glass is also within the scope of the present

invention.

[0020]

(Second Embodiment)

This embodiment shows one example of a brushless motor constituted by the laminate coil of the present invention. The brushless motor shown in Fig. 11 comprises a first rotor 101a comprising an annular magnet 100 having N and S poles alternately as shown in Fig. 12, which is fixed to a yoke 105a becoming a support, a rotation shaft 130 connected to a center of the first rotor 101a, a stator 125 comprising a laminate coil 1 facing the first rotor 101a via a predetermined magnetic gap, an electric signal controller (not shown) for periodically supplying driving electric current to coil poles 50 formed in the laminate coil 1, a PCB on which circuit patterns connected to the input and output terminals formed on the laminate coil 1 are formed, and a bearing 150 fixed to the stator 125 via a bushing 140 and supporting the rotation shaft 130 connected to the first rotor 101a such that the first rotor 101a smoothly rotates. This brushless motor uses three driving power sources. The explanation of the laminate coil 1 per se will be omitted, because it may be the same as in the first embodiment. The annular magnet 100 is preferably made of high-coercivity permanent magnets such as sintered rare earth magnets such as sintered Nd-Fe-B magnets, sintered Sm-Co magnets, etc., bonded rare earth magnets such as Nd-Fe-B, Sm-Fe-N, Sm-Co, etc., or sintered ferrite magnets, etc. Preferably, the use of permanent magnets having a higher intrinsic coercivity Hij than a residual magnetic flux density Br can make the annular magnet 100 thinner. The shape of the annular magnet 100 is not restricted to an integral ring magnet, but may be fan-shaped or rectangular magnets obtained by dividing a ring.

[0021]

A driving electric current is supplied from the electric signal controller to the coil poles 50 in the laminate coil 1, to generate a magnetic field. This

magnetic field reacts with a magnetic field of the annular magnet 100 of the first rotor 101a, to generate an electromagnetic force. A torque is thus generated between the first rotor 101a and the stator 125, resulting in the rotation of the first rotor 101a at a predetermined angle. By supplying the driving electric current from the electric signal controller to the coil pole of each phase successively, the first rotor 105a is continuously rotated.

The laminate coil 1 may have lands for magnetic sensors of the first rotor 101a. This magnetic sensor excites a coil pole corresponding to a position of the magnetic pole of a rotor and gets rotatory power in rotatory direction in a constant direction, but it is constituted by a hole element in many cases. Line patterns connecting the hole element to the PCB, on which circuit patterns are formed, may be formed on the laminate coil 1. A frequency generator (FG) coil may be formed in the laminate coil 1 or on its main surface, and the laminate coil 1 may have a cavity, in which the hole element is disposed. Thus constituted, a thin, high-output motor could be obtained without having a large magnetic gap between the first rotor 101a and the stator 125.

[0022]

Because the input and output terminals are formed on one main surface of the laminate coil 1, it may be mounted directly onto the PCB, resulting in easy electric connection of its terminals to the circuit patterns. Further, because the input and output terminals are formed at four corners of one main surface of the laminate coil 1, they may be arranged around the through-holes 135 of the PCB. Because the laminate coil 1 can be made thin by laminating the coils, and because a ceramic material used for the laminate has high bending strength and Young's modulus, even a thin laminate has sufficient strength. Thus, the rotor can be disposed close to the PCB, resulting in a thin motor. Though the PCB is used in this embodiment, the formation of the laminate coil 1 as a large planar substrate, on which an electric signal controller is disposed, is

also within the scope of the present invention.

[0023]

Fig. 13 shows a further example of the brushless motor of the present invention.

This brushless motor comprises

a first rotor 101a comprising an annular magnet 100 having N and S poles that became a lot of sets, alternately, as shown in Fig. 12, which is fixed to a yoke 105a becoming a support, a second rotor 101b comprising annular magnet 100b, which is fixed to a yoke 105b becoming a support such that the annular magnet 100b opposes the annular magnet 100a with their opposite poles facing each other, a rotation shaft 130 connected to a center of the first rotor 101a and a center of the second rotor 101b, a stator 125 facing the first and second rotors 101a, 101b via a predetermined gap and comprising a laminate coil 1 for applying an electromagnetic force of an opposite direction to the first and second rotors 101a, 101b, a PCB comprising an electric signal controller for periodically supplying a driving electric current to coil poles 50 formed in the laminate coil 1, on which circuit patterns connected to input and output terminals formed on the laminate coil 1 are formed, and is fixed to the stator 125 via a bushing 140 such that the first and second rotors 101a, 101b smoothly rotate with a bearing 150 supporting a rotation shaft connected to the first and second rotors 101a, 101b. This brushless motor uses three driving power sources. The laminate coil 1 used in this embodiment is formed on a large planar substrate, on which circuit patterns such as an electric signal controller for periodically supplying a driving electric current, etc. are integrally formed. Because other structures are substantially the same as those of the first embodiment, their explanation will be omitted.

[0024]

In this double-rotor brushless motor, the stator comprising pluralities of

coil poles is arranged substantially at an intermediate point between the first and second rotors. Each coil pole is arranged such that it attracts or repulses the annular magnets 100a, 100b of the first and second rotors. Accordingly, the first and second rotors receive an attraction or repulsion force in an opposite direction at the same level from the stator. As a result, vibration in the direction of the rotation shaft is more suppressed than in the single-rotor brushless motor. In this embodiment, too, the stator 125 can be made thin with the same gap between the first rotor 101a and the stator 125, and between the second rotor 101b and the stator 125. Accordingly, a thin motor with little vibration can be obtained.

[0025]

Effects of the invention

According to the present invention, it is possible to provide a small, thin laminate coil having high strength and productivity and excellent motor efficiency free from uneven rotation and torque ripple, and a brushless motor comprising such a laminate coil.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view showing a laminated coil according to one embodiment of the present invention;

Fig. 2 is an exploded view showing the internal structure of the laminated coil shown in Fig. 1;

Fig. 3 is a schematic view showing an equivalent circuit of the laminated coil shown in Fig. 1;

Fig. 4

(a) is an enlarged plan view showing an example of pluralities of coils formed on an insulator layer of the laminated coil of the present invention;

(b) is an enlarged plan view showing another example of pluralities of

coils formed on an insulator layer of the laminated coil of the present invention;

Fig. 5

(a) is an enlarged view showing a first coil of the laminated coil according to one embodiment of the present invention;

(b) is an enlarged view showing a second coil of the laminated coil according to one embodiment of the present invention;

Fig. 6 is a partial cross-sectional view showing the laminate coil according to one embodiment of the present invention;

Fig. 7 is an enlarged plan view showing a through-hole of the laminate coil according to one example of the present invention;

Fig. 8 is an exploded perspective view showing the internal connection of the laminate coil according to one embodiment of the present invention;

Fig. 9 is an exploded perspective view showing one example of methods for producing the laminate coil of the present invention;

Fig. 10 is a plan view showing a laminate substrate, on which pluralities of laminate coils of the present invention are formed;

Fig. 11 is a cross-sectional view showing a brushless motor according to one embodiment of the present invention;

Fig. 12 is a plan view showing an annular magnet used in the brushless motor of the present invention;

Fig. 13 is a cross-sectional view showing a brushless motor according to another embodiment of the present invention;

Fig. 14 is a partial enlarged view showing a conventional sheet coil;

Fig. 15 is a partial cross-sectional view showing a conventional sheet coil; and

Fig. 16 is a cross-sectional view showing a brushless motor comprising a conventional sheet coil.

Descriptions of Letters and Numerals

1: Laminated Coil,

10: Through-Hole,

60: First Coil Pole,

61: Second Coil Pole,

62: Third Coil Pole,

200, 201a, 201b, 201c, 210: First Connecting Line,

251a – 251h, 252a – 252h, 253a – 253h: Coil, and

300a – 300c: Second Coil.

Japanese Patent Application No. 2002-229522

ABSTRACT

Problems to be solved:

To provide a small, thin laminate coil having high strength and productivity and excellent motor efficiency free from uneven rotation and torque ripple, and a brushless motor comprising such a laminate coil.

Solution:

A laminate coil for an integral *n*-phase motor (*n* is a natural number of 2 or more) having pluralities of coil poles formed by patterned conductor coils formed in a laminate constituted by pluralities of insulating layers, the laminate coil comprising input and output terminals formed on an outer surface of the laminate, a first connecting line connecting the input terminal to the coil poles, and second connecting lines series-connecting coil poles having the same polarity, the first and second connecting lines being formed by conductor patterns, and the coil poles being formed on pluralities of insulating layers sandwiched by the first and second connecting lines.

Selected Drawings: Fig. 1

Fig. 1

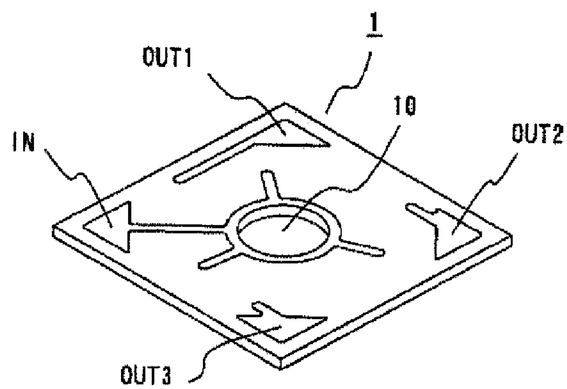
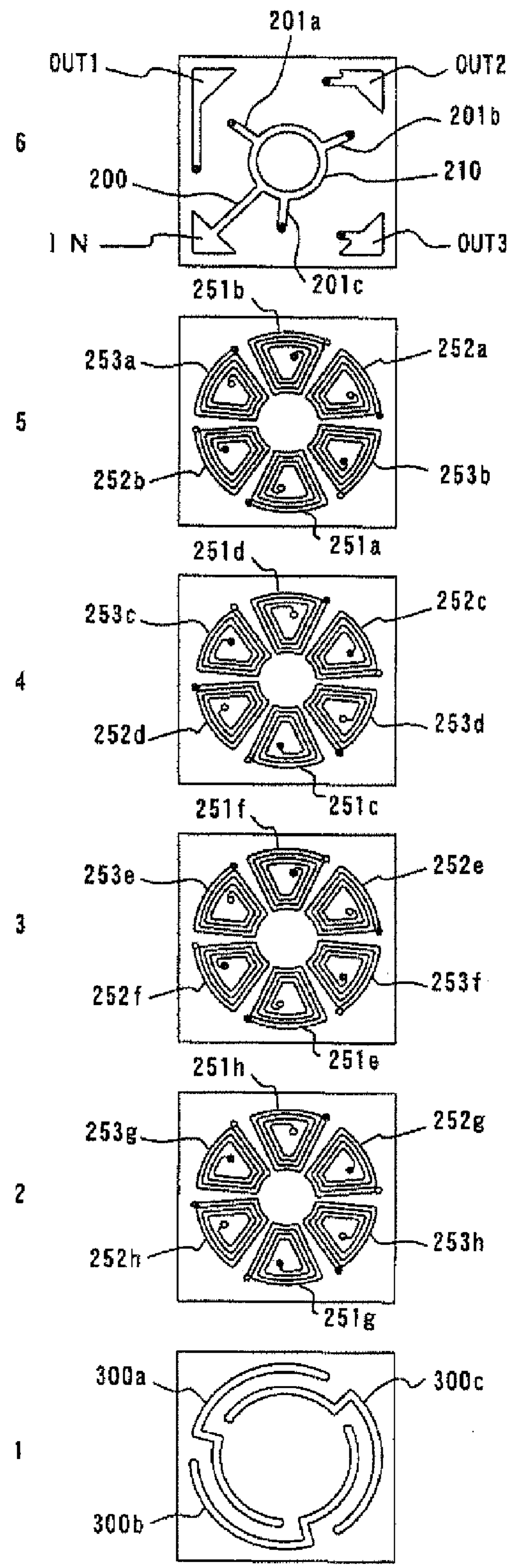


Fig. 2



201a
OUT1
OUT2
201b
6
200
210
I N
OUT3
201c
251b
253a
252a
5
252b
253b
251a
251d
253c
252c
4
252d
253d
251c
251f
253e
252e
3
252f
253f
251e
251h
253g
252g
2
252h
253h
251g
300a
300c
1
300b

Fig. 3

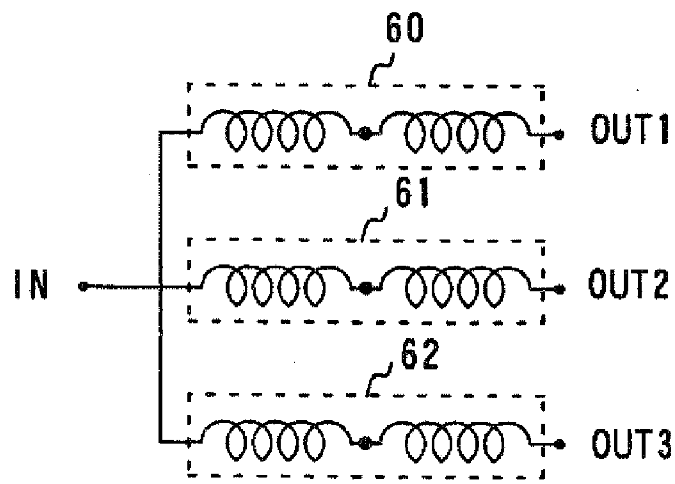
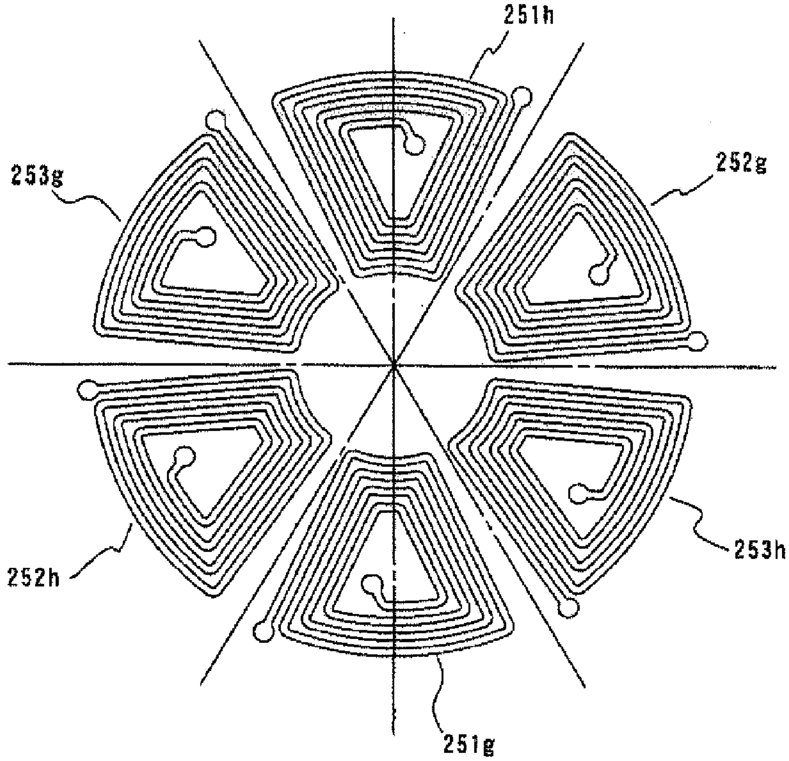


Fig. 4

(a)



(b)

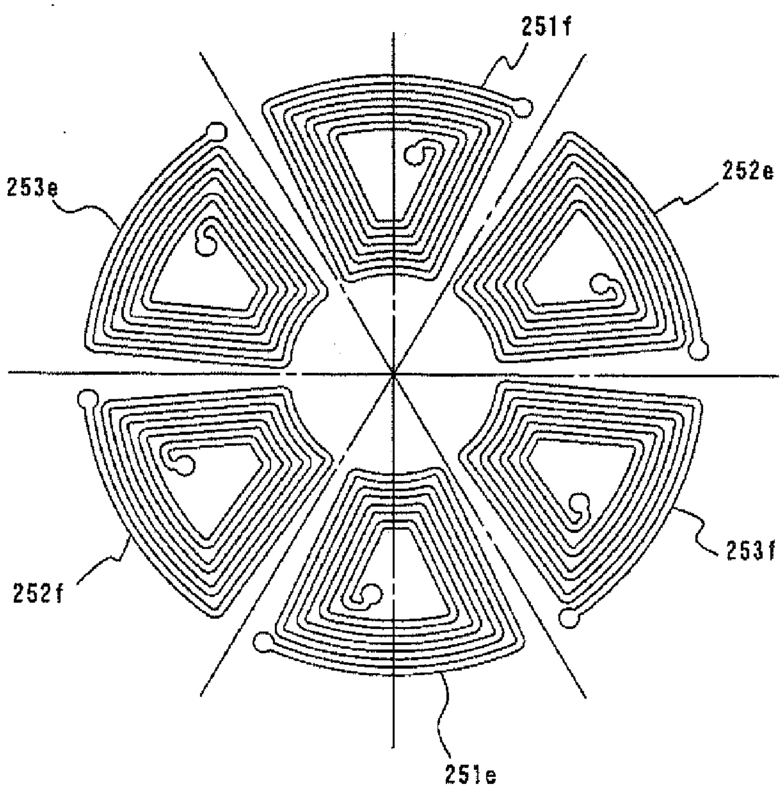


Fig. 5

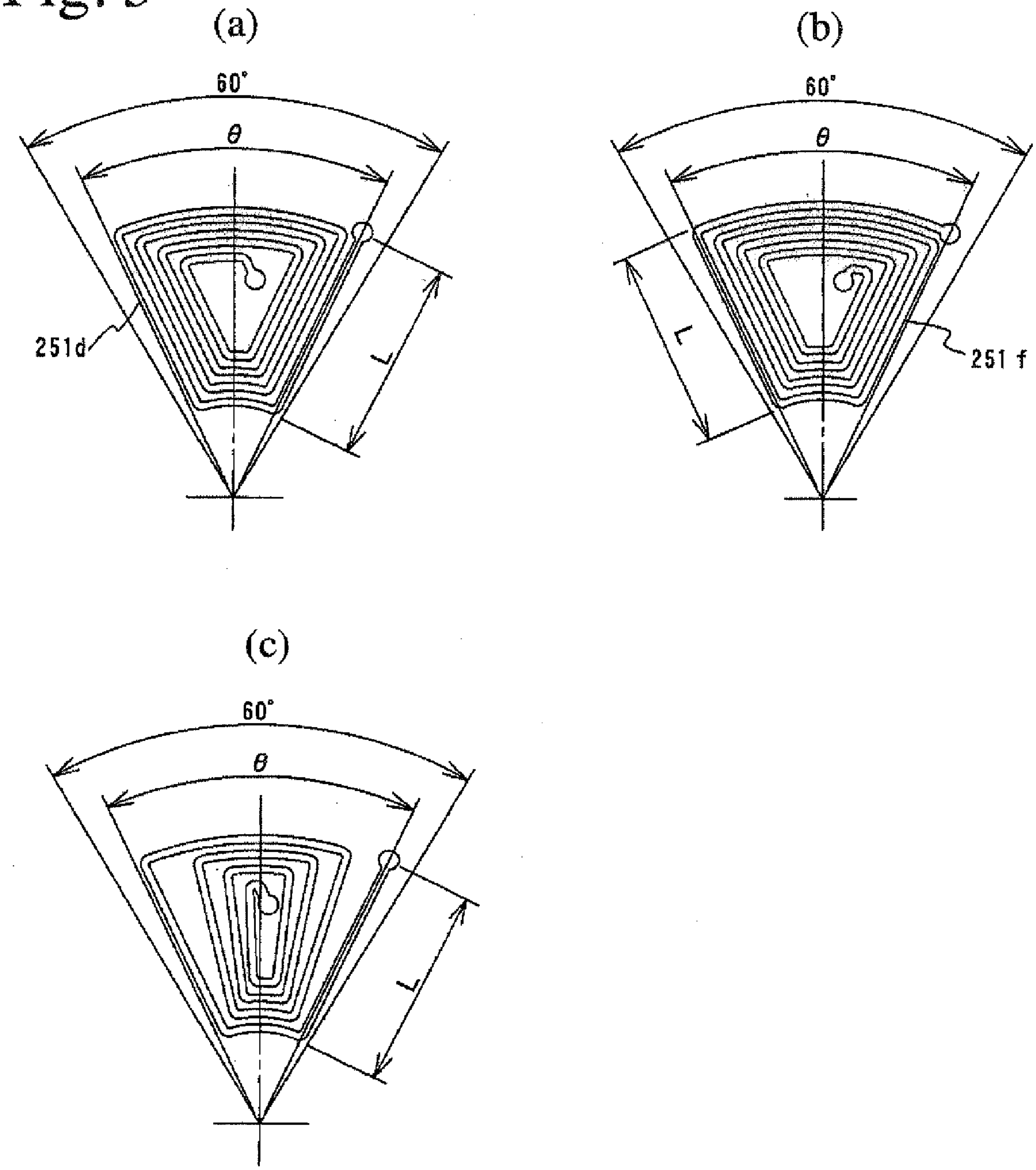


Fig. 6

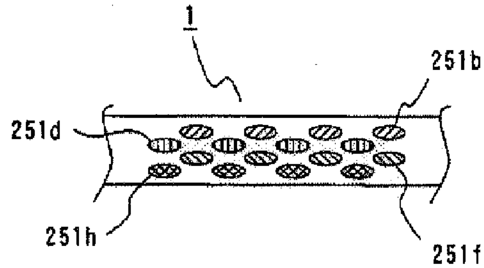


Fig. 7

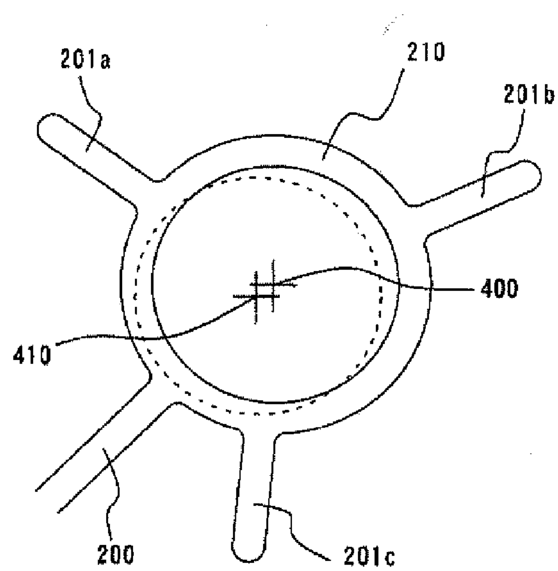
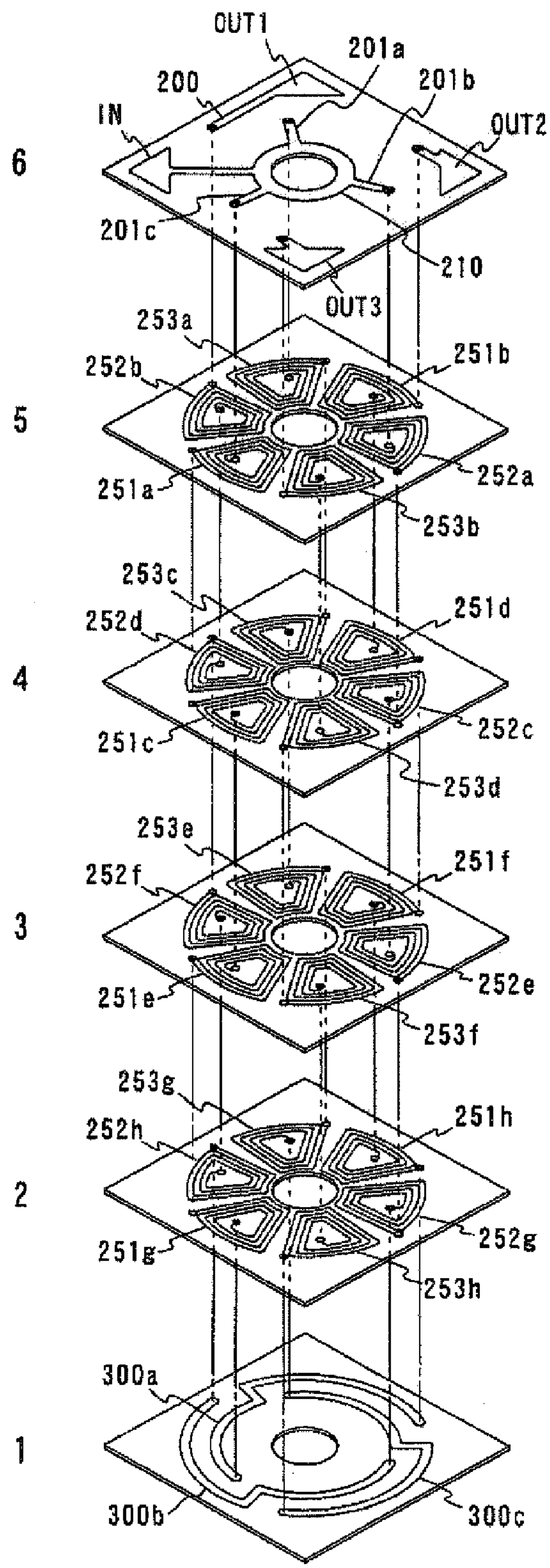


Fig. 8


OUT1
201a
200
201b
IN
OUT2
6
201c
210
OUT3
253a
251b
252b
5
252a
251a
253b
253c
251d
252d
4
252c
251c
253d
253e
251f
252f
3
252e
251e
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253g
251h
252h
2
252g
251g
253h
300a
1
300b
300c

Fig. 9

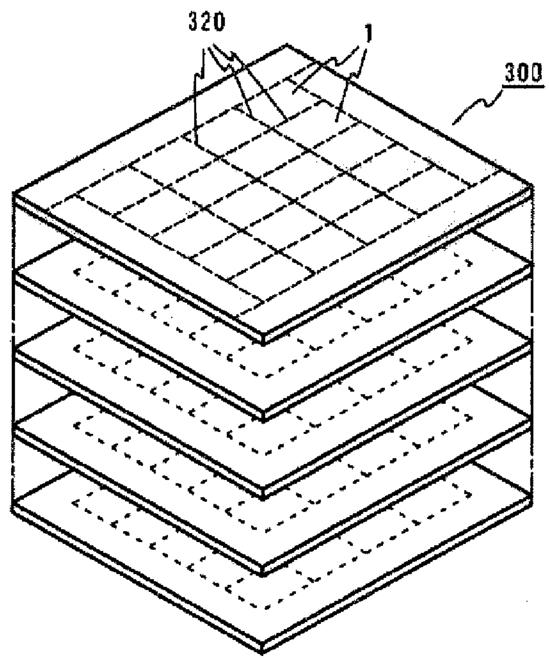

Fig. 10

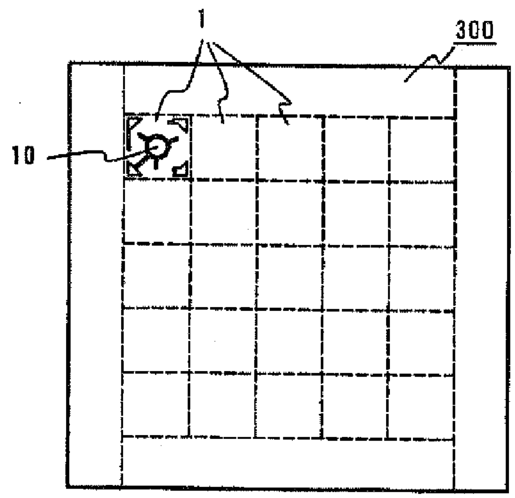

Fig. 11

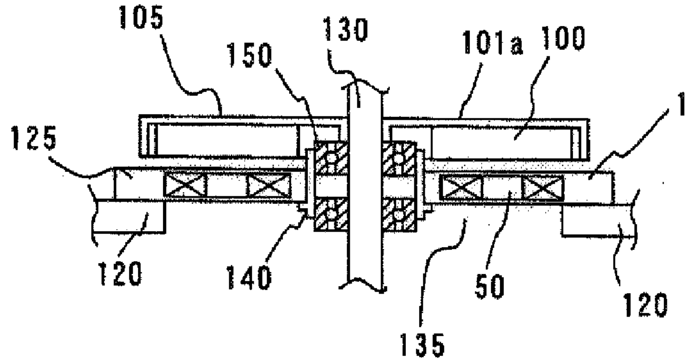

Fig. 12

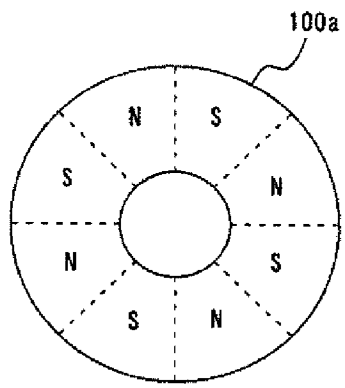

Fig. 13

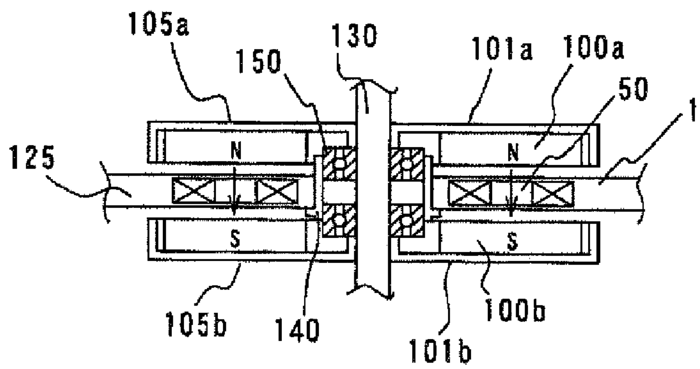

Fig. 14

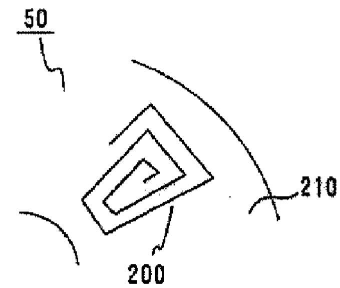

Fig. 15

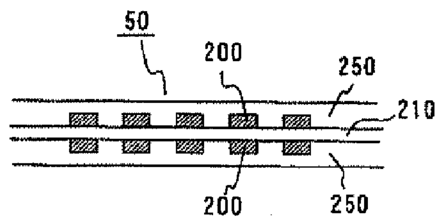

Fig. 16